Assiut Journal of Agricultural Sciences 56 (2) 2025 (210-220)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Effect of Foliar Application of Certain Natural and Chemical Substances on Growth and Fruiting of Strawberry Variety "Sweet Charlie"

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DOI: 10.21608/AJAS.2025.359556.1461

Abstract

The effects of boron, salicylic acid and chitosan on growth, yield components and fruit quality of a strawberry variety (Sweet Charlie) were studied in the 2023 and 2024 seasons. A randomized complete block design was used.

The results showed that the application of boron, salicylic acid and chitosan improved plant height, number of leaves/plants, number of extensions, leaf area, total chlorophyll, number of fruits per plant and yield per plant compared to water spraying (control) increased significantly.

The results also showed that the physical properties of the fruits, i.e., h. Fruit weight, fruit height, fruit diameter and fruit hardness increased significantly when using boron, salicylic acid or chitosan compared to sprayed water (control).

The results also showed that boron, salicylic acid and chitosan spraying significantly improved the chemical composition of the fruits, in terms of an increase in the percentage of total soluble solids, sugar content and vitamin C, as well as a reduction in acidity compared to the control treatment.

It has been suggested that foliar application of chitosan or boron can significantly improve plant growth, yield and fruit quality.

Keywords: *Boron, Chitosan, Foliar application, Salicylic acid, Strawberry.*

Introduction

Strawberry (*Fragaria x ananassa* Duch.) is individual of ultimate main fruit crops developed in Egypt for new devouring, smuggle, and processing on account of allure extreme digestive and medicinal advantage. It is top-secret as narrow product crops belonging to the rosacea kin. Strawberry education extent in Egypt has raised, arriving about 45,714 fed. (1 augment. = 4200 m^2), accompanying a total result of 687,653 tons. According to enumerations from M.A.L.R. (2022), the total amount of exportable fruit was 54,000 tons of new product and about 140,000 tons of stopped light. Recently, the UN World Trade Center reported that Egypt is the realm's champion sender of stopped strawberries. Exports attained 140,000 tons, giving reason for 20% of all-encompassing exports and $165 heap in value, or 14.3% of total all-encompassing exports in 2020 (FAO, 2020).

Received: 15 January 2025/ Accepted: 15 March 2025/ Published online: 21 April 2025

Strawberries are main for human energy because they are a rich source of source of nourishment C, in addition to potassium, iron, and inclusive antioxidants (Halvorsen *et al*., 2002). It still contains extreme amounts of abstinence from food texture, subordinate metabolites, and sugars. The high content of these compounds is in consideration of fitness as they manage prevent ancestry clotting and reduce heart failure (Mohamed *et al*., 2021). However, the characteristics and quota of these compounds are affected by genetic, material, and land determinants (Kallio *et al*., 2000).

The local strawberry variety (Balady) has run-down all the while ancient times although it has received few seductive traits in the way that extreme carbohydrate content and good flavor and perfume of the products. Such a cultivar is characterized by a reduced output. Accordingly, many cultivars have happened brought in to Egypt from Europe and California. These cultivars are setting immediately in a large suggestion of correction the local traditional cultivar (Balady). The intentional light cultivar was popularized to Egypt from USA and it is outlined as following: Sweet Charlie is bred in Florida. Sweet Charlie is an early sweet variety. The plant is medium in size, which makes harvesting easier. Sweet Charlie has anthracnose tolerance and shows promise in the southern states.

Foliar application of micronutrients is clearly an ideal method to avoid problems with nutrient availability. Boron has effects on cell wall structure, cell elongation and root elongation. It is also thought to be a nutrient that increases carbohydrate translocation in the phloem, which can increase soluble solids content in fruits (Marschner, 2012). Boron applications have increased yield and fruit quality (Wojcik and Lewandowski, 2003).

In addition, boron is an important micronutrient essential for the stabilization of certain components such as cell wall structure and function, cell membrane activity, improved cell division, tissue differentiation, and increased net photosynthetic rates as leaf chlorophyll content increases (Rafeii and Pakkish, 2014). and Mohamed *et al*., 2018).

Salicylic acid (SA), a commonly happening phytohormone, acts as a main indicating particle and increases the opposition of discussed plants to abiotic stresses (Khan *et al*. 2012). Salicylic acid again plays a main duty in plant progress, ion rude answer and food transport in the plant bulk. The phenolic compound salicylic acid is present in many plants and is likewise complicated in local and intrinsic opposition to fungal pathogens (Meena *et al*., 2001).

Exogenous application of salicylic acid improved the growth and productivity of the strawberry cultivar Fern, with one, two, three, or four foliar applications of 1.0 mM salicylic acid resulting in the highest values for leaf chlorophyll, leaf elements, initial yield, and total yield. (Karlidag *et al*., 2009 and Kazemi, 2013).

Chitosan is a linear polysaccharide with a random distribution of β-(1-4)-linked D-glucosamines (deacetylated units) and N-acetyl-D-glucosamines (acetylated units); it is a polysaccharide called 2-amino-2-deoxyβ-D-glucosamine; it is also known as chitosan, a highly aminated polysaccharide. Chitosan can be obtained from marine crustaceans such as shrimps, mussels and needlefish or from the exoskeletons of most insects, called

chitin, which can be converted into chitosan by isolation and amination of acetyl groups (Sugiyama *et al*., 2001).

Chitosan is a chemical biopolymer derived from crustaceans and is soluble in organic acids. Chitosan is considered environmentally friendly for use in agriculture because it breaks down easily in the environment and is non-toxic to humans. Chitosan and its derivatives have been reported to induce a natural defense response in plants and are used as natural compounds to combat pathogenic diseases before and after harvest. Antimicrobial activity of chitosan against various plant pathogens has been reported (Rahman *et al*., 2014).

The aim of this study is to investigate the effect of foliar application of boron, salicylic acid and chitosan on the growth and fruiting of Sweet Charlie strawberry plants.

Materials and Methods

The experiment was conducted in two consecutive seasons in 2023 and 2024 at the Agricultural Research Institute's farm in Arab Al-Awamir, Abnub District, Assiut Governorate. Sweet Charlie transplants were purchased as cool plants (Frigo) from a local nursery.

The soil was sandy and prepared by plowing, sowing and fertilizing. A drip irrigation system was used in the experiment.

The area of each experimental plot was 12.80 m^2 and included a bed 8.0 m long and 1.6 m wide. Each bed consisted of four rows and the plants were spaced 0.25 m apart rows and transplanted 0.15 m within a row. Transplanting took place on September 20 (60 days after sowing) when the plants reached 3-4 true leaves. The four treatments were administered in a completely randomized block design with four replicates, with each experimental plot consisting of five 2 m rows. All other cultural practices required for strawberry cultivation were carried out in accordance with the recommendations of the Egyptian Ministry of Agriculture.

These experimental treatments were control treatments (water spray), boron as boric acid (17% B) at 3 mg/L, salicylic acid at 3 mm/L, and chitosan at 3 mg/L.

For boric acid and salicylic acid treatment, the powders were dissolved in hot water, allowed to cool and then applied to the plant material.

A stock solution (2% w/v) of chitosan was prepared by dissolving chitosan in 0.5% (v/v) glacial acetic acid with constant stirring and the pH was adjusted to 5.6 with 1 N NaOH. The stock solution was sterilized at 121 °C for 20 minutes and then adjusted to lower concentrations (e.g., 5 mg/l) by appropriate dilution with distilled water (Du *et al*., 1997).

Three spray applications of each treatment were performed one month apart. The first application was 6 weeks after transplantation. Triton B was added as a wetting agent in an amount of 0.05% to the entire spray solution before use. Foliar applications were carried out with a manual pump sprayer until dripping.

1. Characteristics of Vegetative growth

Ten flowering plants were randomly selected from each plot; The average of ten plants was taken as one replicate. The following characteristics were recorded for each plant

-Plant height (cm).

-Number of leaves per plant.

-Number of elongations per plant.

-Leaf area (cm^2)

-Total chlorophyll count (SAPD)

2. Yield components

Number of fruits per plant.

Total yield weight (g): Total yield per plant was calculated by measuring the weight of fruits harvested during the growing season at full ripeness (full red color).

3. Physical characteristics

20 fruits from each replicate were randomly collected at harvest time and the following characteristics were measured

Average fruit weight (g): calculated by dividing the total harvest weight (g) by the number of fruits on the plant.

Fruit length (L) (cm) and Fruit diameter (D) (cm): They were estimated by using Vernier caliper

Fruit firmness (kg/cm^2): It was estimated by using penetrometer.

Chemical characteristics of fruits: The same samples used for physical characterization were used to measure the following attributes

Total soluble solids % (TSS): Measured with a hand refractometer.

Total sugars % and reducing sugars%: Determined according to the Lane and Eynon method described in (AOAC (1990).

Total titratable acidity%: Determined by titration of pure fruit juice with 0.1 N NaOH with phenolphthalein as indicator (AOAC, 1990). Acidity was calculated as g citric acid/100 ml juice.

The content of vitamin C: Analysis was performed according to the standard method described in AOAC (1990) and expressed as mg/100 g.

Statistical analysis

All data obtained was statistically evaluated. Analysis of variance (ANOVA) was performed according to the method of Snedecor and Cochran (1991).

Results

Plant growth parameters

The data in Tables (1) and (2) show the effect of boron, salicylic acid and chitosan on the plant growth parameters of Sweet Charlie strawberry plants in the 2023 and 2024 seasons. From the data, similar trends were observed between the two examined seasons.

The results showed that the application of boron, salicylic acid and chitosan significantly increased plant height, number of leaves/plants, number of extensions, leaf area and total chlorophyll compared to water spraying (control). In this regard, the application of boron, salicylic acid and chitosan resulted in the highest plant height (20.85, 21.25 and 21.70 cm, respectively) and number of leaves per plant (21.50, 22.20 and 24.45, respectively, averaged over two seasons). Plants sprayed with water had the lowest significant values, recording average values of 18.00 and 18.00 cm for the two seasons. No significant differences were observed when using boron and salicylic acid. It can be concluded that from an economic point of view the use of salicylic acid or chitosan was preferred.

Regarding leaf area and total chlorophyll; Boron, salicylic acid and chitosan had a positive influence on these growth parameters compared to the control. Boron and chitosan had the highest leaf area (463.10 and 487.80 cm^2) and total chlorophyll, followed by boron (39.15 and 39.35 SAPD averaged over two seasons). In contrast, the control had the lowest leaf area (424.65 cm^2) and total chlorophyll (35.00 SAPD). For the control, boron, salicylic acid and chitosan, leaf areas of 424.65, 463.10, 458.80 and 487.80 cm^2 were recorded. The percentage increase in leaf area as a result of the treatments compared to the control was 10.54, 8.86 and 15.87%, respectively.

Table 1. Effect of boron, salicylic acid, and chitosan spraying on growth traits of Sweet Charlie strawberry plants during 2023 and 2024 seasons.

Char.	Plant height (cm)			leaves number/plant			Number of elongations		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
Control	18.00	18.00	18.00	17.70	18.30	18.00	4.40	5.30	4.85
Boron	20.70	21.00	20.85	20.30	22.70	21.50	4.90	5.40	5.15
Salicylic Acid	21.00	21.50	21.25	21.40	23.00	22.20	5.10	5.80	5.45
Chitosan	21.60	21.80	21.70	23.20	25.70	24.45	5.13	5.90	5.52
LSD 5%	0.88	0.64	0.54	0.96	1.13	0.75	0.16	0.21	0.13

Table 2. Effect of boron, salicylic acid, and chitosan spraying on leaf area and total chlorophyll of Sweet Charlie strawberry plants during 2023 and 2024 seasons.

Char.	Leaf area (cm^2)			Total chlorophyll (SPAD)		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean
Control	440.6	408.7	424.65	35.9	34.1	35.00
Boron	483.4	442.8	463.10	39.1	37.2	38.15
Salicylic Acid	479.4	438.2	458.80	39.9	38.4	39.15
Chitosan	511.3	464.3	487.80	40.1	38.6	39.35

LSD 5%	11.24	10.83	6.52	2.45	2.11	1.65

Yield components

Data in Table (3) show the effect of boron, salicylic acid and chitosan on yield components of Sweet Charlie strawberry in seasons 2023 and 2024.

The results showed that the application of boron, salicylic acid and chitosan significantly increased the number of fruits per plant and yield per plant compared to water spraying (control). The highest yield was achieved with the application of chitosan, which was found to be the best agent.

The recorded number of fruits per plant was (15.25, 17.80, 17.10 and 18.10 fruits respectively) and the yield per plant (average values for the two seasons studied were (413.40, 561.20, 525 .50 and 533.75) due to spraying water (control), boron, salicylic acid and chitosan, respectively.

The yield per plant increased by the corresponding percentages compared to the control due to the treatments achieved (the average values for the two seasons studied were 39.70, 30.73 and 36.83%, respectively). No significant differences were found by spraying chitosan or salicylic acid.

Table 3. Effect of boron, salicylic acid and chitosan spraying on yield components of Sweet Charlie strawberry plants during 2023 and 2024 seasons.

Char.	Fruit number / plant			Yield weight / plant (g)		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean
Control	14.8	15.7	15.25	401.3	425.5	413.40
Boron	16.6	19.0	17.80	553.6	568.8	561.20
Salicylic Acid	17.3	16.9	17.10	521.2	529.8	525.50
Chitosan	18.6	17.6	18.10	525.9	541.6	533.75
LSD 5%	1.05	0.98	0.78	28.25	22.31	18.29

Fruit quality

A. Fruit physical characteristics

The data in Table (4) shows the effects of boron, salicylic acid and chitosan on the physical properties of Sweet Charlie strawberries in the 2023 and 2024 seasons. From the data it is clear that the results during the two seasons studied show a similar trend had.

The results showed that the physical properties of the fruits, i.e., h. Fruit weight, length, diameter and firmness were significantly improved by the application of boron, salicylic acid or chitosan compared to the water-sprayed fruits (control). The highest values were achieved when using chitosan. The recorded fruit weights were (27.20, 30.95, 30.25 and 31.55 g) and fruit lengths (4.88, 5.17, 5.16 and 5.50 cm as average for the two study seasons). The percentage increase in fruit weight in the treatment compared to the control was 15.20%, 11.76% and 17.16%, respectively. Chitosan showed the highest fruit diameter (3.73 cm), followed by boron (3.65) cm and salicylic acid with 3.63 cm compared to the control (3.52) on average over the two seasons. On

the other hand, the control had the lowest fruit firmness (average 1.35 kg/cm^2 over the two seasons).

Regarding fruit firmness, boron, salicylic acid and chitosan all had a positive influence on fruit firmness compared to the control. Chitosan showed the highest fruit firmness (1.92% kg/cm^2), followed by boron (1.66% kg/cm^2 averaged over the two seasons). On the other hand, the control had the lowest fruit firmness (average 1.35 kg/cm^2 over the two seasons). Fruit firmness was 1.35, 1.66, 1.54 and 1.92 kg/cm^2 for control, boron, salicylic acid and chitosan, respectively. The percentage increase in fruit firmness was (20.0, 10.0 and 37.14%) for the treatments compared to the control. Therefore, it was concluded that from a general economic point of view it is desirable to use boron or chitosan.

Table 4. Effect of boron, salicylic acid and chitosan spraying on fruit traits of Sweet Charlie strawberry during 2023 and 2024 seasons.

Char.	Fruit weight (g)			Fruit length (cm)			Fruit diameter (cm)			Fruit firmness (kg/ cm^2)		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
Control	27.30	27.10	27.20	4.83	4.92	4.88	3.42	3.61	3.52	1.40	1.30	1.35
Boron	31.10	30.80	30.95	5.12	5.22	5.17	3.60	3.69	3.65	1.65	1.66	1.66
Salicylic Acid	30.40	30.10	30.25	5.11	5.21	5.16	3.58	3.67	3.63	1.54	1.54	1.54
Chitosan	31.70	31.40	31.55	5.26	5.73	5.50	3.69	3.77	3.73	1.90	1.93	1.92
LSD 5%	0.84	0.91	0.63	0.19	0.16	0.13	0.12	0.08	0.06	0.08	0.06	0.05

B. Fruit chemical characteristics

The results in Tables (5) and (6) show that the application of boron, salicylic acid and chitosan improves the chemical composition of fruits in terms of increasing TSS significantly improved. %, sugar and vitamin C (V.C) content and decrease in acidity compared to control treatment. Table (5) shows that foliar application of chitosan and boron in this order gives better results in terms of TSS (8.24 and 7.85%), total sugars (6.39 and 6.08%) and reducing sugars (4, 90 and 4.70%). In contrast, the control plants were the lowest in this regard for the three traits measured (7.03, 5.47 and 4.20%, respectively).

The TSS was (7.03, 7.85, 7.57 and 8.24%) and the total sugar content was (5.47, 6.08, 5.95 and 6.39% (average of two seasons)). The percentage increase in total sugar content was (12.48, 9.40 and 17.78%) as boron, salicylic acid and chitosan were compared with the control, respectively.

When sprayed with water (control), boron, salicylic acid and chitosan, V.C. The content was 155.40, 171.05, 167.00 and 174.15 mg/100 g (averaged over two seasons), respectively. The percentage increase in V.C. content (6.93, 7.38 and 12.02%) with the application of boron, salicylic acid and chitosan, respectively, compared to the control.

As for the percent acidity, all treatments reduced this parameter compared to the control, obtaining lower values for chitosan and boron (0.65% and 0.68%, respectively, averaged over the two seasons). On the other hand, the control treatment showed the highest value in this regard (0.75% on average over two seasons).

In general, the chemical composition of fruits, except acidity, had the lowest percentage in the control. However, fruits sprayed with chitosan or boron had the highest values in this regard.

Table 5. Effect of boron, salicylic acid and chitosan spraying on TSS and sugar contents of Sweet Charlie strawberry fruits during 2023 and 2024 seasons

Char.	TSS %			Total sugar %			Reducing sugar %		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
Control	6.92	7.14	7.03	5.20	5.73	5.47	4.00	4.40	4.20
Boron	7.74	7.96	7.85	5.83	6.32	6.08	4.50	4.90	4.70
Salicylic Acid	7.46	7.67	7.57	5.75	6.15	5.95	4.00	4.70	4.35
chitosan	8.14	8.34	8.24	6.11	6.67	6.39	4.70	5.10	4.90
LSD 5%	**0.32**	**0.29**	**0.18**	**0.19**	**0.16**	**0.11**	**0.12**	**0.11**	**0.07**

Table 6. Effect of boron, salicylic acid and chitosan spraying on acidity and V.C of Sweet Charlie strawberry fruits during 2023 and 2024 seasons

Char.	Acidity %			V.C (mg / 100g)		
Seasons / Treat.	2022	2023	Mean	2022	2023	Mean
Control	0.77	0.73	0.75	148.0	162.8	155.40
Boron	0.68	0.67	0.68	162.5	179.6	171.05
Salicylic Acid	0.74	0.73	0.74	159.4	174.6	167.00
Chitosan	0.65	0.64	0.65	166.1	182.2	174.15
LSD 5%	**0.023**	**0.031**	**0.016**	**6.34**	**7.11**	**4.10**

Discussion

From this study, foliar application of boron significantly increased growth characteristics. This may be due to the physiological role of boron and its involvement in protein metabolism, pectin synthesis, maintenance of proper water balance in the plant, adenosine triphosphate (ATP) resynthesis and sugar translocation during flowering and fruiting (Meena *et.al*., 2001). The application of boron was very beneficial in the photosynthesis process as it promoted carbohydrate accumulation and ultimately improved fruit quality (Singh *et al*., 2012 and Mohamed *et al*., 2021).

Salicylic acid is a phenolic endogenous growth regulator, normally produced in very small amounts in plants, that regulates a range of physiological and biochemical processes in plants, including seed germination, plant growth, flowering induction, nutrient uptake and transport, water-plant relationships, membrane permeability, stomatal conductance, photosynthesis and enzyme activity (Arfan *et al*. (2007); Hayat *et al*. (2010); Youssef *et al*. (2017) and Mohamed *et al*. (2018)).

Chitosan is widely used in agriculture, mainly to promote plant defense (Naeem *et al*., 2010). Chitosan also promotes plant growth, development and productivity and improves the yield components of various crops (El-Tantawy (2009); El-Tanahy *et al*. (2012) and El-Miniawy *et al*. (2013)).

In the current study, chitosan, boron or salicylic acid played an important role in regulating a number of vital processes, including plant growth, and increased vegetative

growth traits. Then these were attributed to an increase in yield and an improvement in fruit quality.

The results of this study are consistent with those of other researchers such as Martin-Mex *et al*., 2005; Arfan *et al*., 2007; Hayat *et al*., 2010; Singh *et al*., 2012; El-Miniawy *et al*., 2013; Youssef *et al*., 2017; Mohamed *et al*., 2018; Mohamed *et al*., 2021 and Masoud *et al*., 2024

Conclusion

The results of this study showed the effects of boron, salicylic acid and chitosan on plant growth, yield and fruit quality. It is believed that foliar application of chitosan or boron could significantly improve plant growth, yield and fruit quality of Sweet Charlie strawberry.

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تأثير الرش الورقي ببعض المواد الطبيعية والكيميائية على نمو وإثمار الفراولة صنف "سويت تشارلي"

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الملخص

تم دراسة تأثير الرش الورقي للبورون وحمض الساليسيليك والشيتوزان على النمو ومكونات المحصول وخصائص الثمار نباتات الفراولة (سويت تشارلى) خلال موسمي 2023، 2024.

حيث تم الرش الورقي بالبورون بتركيز3 ملجم / لتر وحمض الساليسيليك بتركيز3ملجم / لتر والشيتوزان. بتركيز3 ملجم / لتر وقد تم تصميم التجربة بنظام القطاعات كامله العشوائية.

وقد أظهرت النتائج أن رش البورون وحمض الساليسيليك والشيتوزان أدى إلى زيادة معنوية في طول النبات وعدد الأوراق / النباتات وعدد االمدادات ومساحة الورقة والكلوروفيل الكلي مقارنة بالكنترول المعامل بالماء.

كما أظهرت النتائج أن رش البورون وحمض الساليسيليك والشيتوزان أدى إلى زيادة معنوية في عدد الثمار لكل نبات وكمية المحصول لكل نبات مقارنة بالكنترول.

كما أظهرت النتائج أن الخصائص الفيزيائية للثمار، من وزن الثمار وارتفاع الثمار وقطر الثمار وصلابة الثمار، زادت معنويا عند رش البورون أو حمض الساليسيليك أو الشيتوزان مقارنة بالكنترول.

كما أظهرت النتائج أن إضافة البورون وحمض الساليسيليك والشيتوزان أدى إلى تحسين التركيب الكيميائي للثمار بشكل ملحوظ من حيث زيادة نسبة المواد الصلبة الذائبة الكلية ومحتوى السكر وفيتامين ج وخفض الحموضة مقارنة بمعاملة الكنترول .

ومن ناحية أخرى أظهرت الثمار المرشوشة بالشيتوزان أو المعاملة بالبورون أعلى القيم في هذا الصدد.

وعليه يمكن التوصية بأهمية الرش الورقي بالشيتوزان أو البورون وذلك لتحسين النمو الخضري للنباتات مع زيادة الإنتاجية وجودة الثمار.

الكلمات المفتاحية: *البورون، الشيتوزان، الرش الورقي، حمض الساليسيليك، فراولة.*